Mindfulness Disposition and Neural Correlates of Emotional Perception

Honors Research Thesis

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Abstract

Mindfulness disposition, defined as the ability to focus on present moment experiences, has been associated with enhanced attentional and emotional control. In this study, we examined if higher levels of mindfulness disposition in older adults were associated with the cortico-subcortico circuitry involved in emotional processing. Forty-four participants (25 older adults, 19 younger adults) performed an emotional perception task inside the scanner, and filled out questionnaires related to overall health and mindfulness disposition. Consistent with previous research, we found older adults to show increased recruitment of the prefrontal cortices, specifically the medial prefrontal cortices (mPFC) while processing negative, relative to neutral information. Mindfulness disposition was found to be associated with the neural regions supporting emotional perception. Higher levels of mindfulness disposition in older adults were associated with diminished reactivity of the orbitofrontal cortex and amygdala during the affect block, thus suggesting one pathway through which mindfulness training may enhance emotional regulation. Overall, our results indicate that mindfulness disposition may optimize the neural circuitry associated with emotion perception in older adults.

Mindfulness Disposition and Neural Correlates of Emotional Perception

Old age is typically accompanied by bodily deterioration, increasingly frequent health problems, mobility losses, and memory failures (Carstensen, Fung, Gross 1998; Buckner, 2004; Dennis & Cabeza, 2008). One would imagine that with all these hardships older adults are more emotionally distraught than young adults. However, despite the health, social, and psychological difficulties that accompany old age, older adults are emotionally well-adjusted (Carstensen, Pasupathi, Mayr, & Nesselroade, 2000). Additionally, they have been shown to focus more on the emotional meaning of information and how an experience makes them feel (Mather & Carstensen, 2005) than do young adults. In fact, research has shown that high levels of affective well-being and emotional stability are typical in older adults (e.g., Carstensen et al., 2000; Charles, Reynolds. & Gatz, 2001; Kessler & Staudinger, 2009; Kunzmann, Little, & Smith, 2000; Mroczek & Kolarz, 1998; Teachman, 2006).

Multiple theories have been proposed to explain why aging is accompanied with this surprising increase in emotional well-being. One such theory is the socioemotional selectivity theory (Carstensen, 1993), which suggests that older adults may be more focused on optimizing their emotional experience than young adults because older adults are closer to the perceived end of life than young adults. This change in time perspective is believed to lead to an increased emphasis on emotional goals and emotional content of information (Carstensen, Fung, & Charles, 2003). Alternatively, the life-span theory of control suggests that the capacity to control one's environment declines with age (Heckhausen & Schulz, 1995). As a result, older adults are less likely to attempt to change their environment and situations and are more likely to instead adjust their self-views through emotion regulation in order to adapt to the situation (Heckhausen & Schulz, 1995; Heckhausen, Wrosch, & Schulz, 2010). Despite variation in these proposed theories explicating older adults' enhanced affective functioning, it is clear that emotion regulation plays a crucial role in aging.

Emotion regulation is defined as “the process by which individuals influence which emotions they have, when they have them, and how they experience and express these emotions” (Gross, 1998a, p. 275). It also refers to the ability to exert control over emotional responses. Research suggests enhanced affective functioning and superior emotion regulation in the elderly (Ochsner & Gross, 2005). Blanchard-Fields (2007) posits that this global improvement in regulation in older adults may be related to an advanced ability to adapt regulation strategies according to the stressor.

In order to better understand these age-related differences in emotion regulation capabilities, it becomes essential to examine the underlying neural mechanisms involved in emotional processing. While a multitude of brain regions are involved in the neural processing of emotionally salient events (Phan et al., 2002), the automatic processes of the amygdala and controlled processes of the prefrontal cortex (PFC) are among the most critical. The amygdala, a region of the limbic system is a main player in the processing of social-emotional stimuli (Adolphs, 2003; Baron-Cohen, 2003; Brothers, 1990). This subcortical structure is responsible for the automatic detection of emotions as well as the generation of corresponding physiological responses. Functional imaging studies (Irwin et al., 1996; Morris et al., 1996) demonstrate amygdala activation during the processing of threatening stimuli (LeDoux, 1995, 1996) specifically with the left lateralized amygdala putatively playing a special role in the detection of arousing stimuli (Glascher & Adolphs, 2003). Alternatively, the PFC is responsible for the controlled processes involved in processing emotionally salient events. The PFC is primarily involved in the exertion of modulation and control over emotions (Ochsner &

Gross, 2005), with medial and lateral sub-regions supporting different neural processes. The medial PFC (mPFC) coordinates the generation and regulation of affect (Phan, et al., 2002) and has been implicated in tasks involving ‘mentalising’ (Frith & Frith, 1999, 2003), which involves the perception of others’ emotions (Baron-Cohen, 2003; Castelli et al. 2002; Castelli, Happe, Frith, & Frith, 2000). The lateral PFC (lPFC) plays a role in the integration of cognitive and emotion information (Ekman & Davidson, 1994; Dalgleish, & Power, 1999; Martin & Clore, 2001) and is therefore thought to be related to the controlled processes that contribute to emotion regulation.

While it is suggested that both older and young adults use a largely similar network for emotion regulation (Winecoff, 2010) they demonstrate age-related differences in the activation of these regions. Specifically, older adults exhibit activation patterns indicative of increased cognitive control during emotion regulation, such that there is a reduction in subcortical activation during exposure to negative stimuli, coupled with an increase of activation in cortical areas associated with executive control, that is the lateral and the medial prefrontal cortices (Samanez-Larkin, & Carstensen, 2011). Specifically, this includes an age-related decrease in amygdala activation, coupled with the increase in prefrontal cortex activation. This specific pattern of activation has been referred to as Fronto-Amydalar Age-related Differences during Emotional Perception (FADE; St. Jacques, 2009) and is thought to depict the controlled cognitive processes of the PFC exerting top-down modulation of the amygdala, consequently dampening its automatic response. The FADE pattern exhibited by older adults is supportive of previous research, which suggests that emotional well-being in aging has been associated with a shift from automatic processing to more controlled processing of emotions (Williams, et al., 2006). This suggests that older adults may engage in more controlled processes during the perception of emotional stimuli. Research has shown that individuals with better cognitive control are better able to regulate their emotions (Schmeichel, Volokhov, & Demaree, 2008).

At the individual level, these age-related changes in emotion regulation are thought to lead to positive changes in overall mood, the most common being an increase of positive affect and a decrease of negative affect (Carstensen et al, 2000). This change towards increased positive affect highlights the importance emotion regulation plays in the life of older adults. While research suggests that emotion regulation tends to improve with age, there are inevitably individual differences in this process, and not every older adult follows the predicted trajectory of enhanced emotional well-being. Therefore, discovering avenues to improve emotion regulation could help ensure high levels of affective well-being and emotional stability for older adults, overall improving their quality of life. Recent research suggests that one such path for the enhancement of emotion regulation is the practice of mindfulness.

Mindfulness disposition, defined as the ability to be attentive and aware of present moment experiences (Brown & Ryan, 2003), is characterized by curiosity, openness, and acceptance (Bishop et al, 2004). Although multiple definitions of mindfulness have been proposed, all are fundamentally founded in nonjudgmentally focusing attention on present moment experiences. In order to do so, mindfulness requires surveillance of what is simultaneously occurring internally and externally in one’s environment. Thus, a key component of mindfulness is perceptual clarity to one’s emotional state. This vividness of one’s emotional state enables the individual to observe “a bare display of what is taking place” (Shear & Jevning, 1999). One example of being mindful would be paying attention to the smell, taste, and texture of one’s food versus mindless snacking.

The practice of mindfulness has been shown to have various health benefits. Recent research provides evidence for an association between mindfulness and reduced negative affect, stress, mood disturbance, and disease-specific healthy symptoms across many patient populations (Brown & Ryan 2003; Baer, 2003). Mindfulness practices are often integrated into clinical usage and therapies for health improvement (Martin, 1997). For example, Dialectical behavior therapy (DBT; Linehan, 1993), incorporates mindfulness practices from Zen Buddhism, and has been shown to be effective in the treatment of borderline personality disorder (Linehan et al., 1999). Additionally, Mindfulness-based Cognitive Therapy (MBCT) used to treat depression (Segal et al., 2002), has been shown to prevent recurrence of depressive episodes. In addition to these therapeutic modes of mindfulness is the Mindfulness-based Stress Reduction (MBSR; Kabat-Zinn, 1990), which is a structured group program of mindfulness training. This intervention program, founded by Jon Kabat-Zinn, incorporates multiple forms of mindfulness practice, including formal and informal meditation practice, as well as hatha yoga (Kabat-Zinn, 1990). Formal practices of mindfulness include breath-focused attention, body scan-based attention to sensory experiences, as well as both walking and eating meditations. Informal practices incorporated into the intervention include momentary pauses where individuals shift attention to present moment sensory experiences. MBSR has been shown to modify distorted patterns of self-view (Goldin, Ramel & Gross, 2009); enhance behavioral self-regulation (Lykins & Baer, 2009); reduce the routine tendency to emotionally react to transitory thoughts and physical sensations (Ramel, Goldin, Carmona, &McQuaid, 2004;Teasdale et al., 2000); improve allocation of attention (Jha, Krompinger, & Baime, 2007); and reduce stress, depression and anxiety symptoms (Chiesa & Serretti, 2009; Evans et al., 2008; Segal, Williams, & Teasdale, 2002). Theorists suggest that mindfulness training may reduce these symptoms of stress and negative affect by modifying emotion regulation abilities (Chambers, Gulone, & Allen, 2009).

This association between mindfulness and emotion regulation has been somewhat examined in the young adult population. Employing an affect labeling task, Creswell et al. (2007) examined the neural correlates of mindfulness disposition in young adults. In this task, participants saw a target face on screen, and were asked to label the emotion displayed by the target face with one of two words displayed on the bottom of the screen. Results showed that dispositional mindfulness was associated with greater widespread PFC activation, including the mPFC, right and left ventrolateral prefrontal cortex, right dorsolateral prefrontal cortex (dlPFC), and the left insula. Interestingly, participants high in mindfulness disposition demonstrated strong inverse relationships between activity in PFC regions and the right amygdala. In contrast, participants low in mindfulness did not show these effects. These results suggest that mindfulness may be associated with enhancements in these neural affect regulation pathways in young adults through more efficient PFC inhibition of amygdala responses during affect labeling.

The present study aims to extend this literature by examining changes in the cortico-subcortico circuitry involved in emotional processing as a function of mindfulness disposition in older adults. To our knowledge, this is the first study that examines the effects of mindfulness disposition on emotional perception in older adults. Based on previous literature, we hypothesize that mindfulness disposition will be associated with an efficient recruitment of the neural circuitry involved in emotional perception. Specifically, we expect that higher levels of mindfulness disposition in older adults will be associated with an increase in activation of PFC regions, in particular the mPFC and lPFC, coupled with diminished amygadala activation during viewing of negative emotional stimuli. These predictions are consistent with the FADE pattern and would imply that mindfulness disposition has the capability of enhancing the neural circuitry involved in emotion regulation.

Methods

Participants

Twenty-five older adults (19 female, 6 male; mean age =65.8 years) and nineteen young adults (11 female, 8 male; mean age= 24.5 years) were recruited from the greater Columbus area. Inclusionary criteria for participation included being 60 to 75 years of age for older adults and 18 to 30 for young adults; a score higher than 23 on the Mini-Mental Status Examination (Folstein et. al, 1975); corrected visual acuity of 20/40 or better; right-handedness; absence of a self-reported history of psychiatric or neurological disorders; absence of chronic inflammation or hypertension; and suitability for participation in MRI environment. Participants were recruited via newspaper advertisements and Research Match, an online registry of volunteers willing to learn more about and participate in research studies. Additionally, young adult participants were recruited from Ohio State campus via flyers, Research Match, and word of mouth. All participants were compensated for their time. The Ohio State University Institutional Review Board approved the study, and all participants provided informed consent.

Materials

Mindfulness Attention Awareness Scale

All participants were administered the Mindfulness Attention and Awareness Scale (MAAS, Brown & Ryan, 2003) to assess trait levels of mindfulness disposition. MAAS is a 15-item, single factor questionnaire designed to assess one's ability to focus on present moment experiences and disengage from a mechanical, "auto-pilot" mode of functioning. All items are rated on a six-point likert scale (almost always – almost never), and the questionnaire has been shown to have good internal consistency and test-retest reliability (Brown & Ryan, 2003). Cronbach's alpha for this measure in our study was 0.90.

Observe and Label task

In the MRI scanner, participants completed an Observe and Label task, which was based on an in-scanner block design. This task involved two conditions, an affect condition and a neutral condition. In each trial, either a neutral face showing no emotion or an affect face showing a specific emotion was presented on the screen for one second. Expressive emotions were limited to anger, fear, or disgust. All faces were chosen from the NimStim Set of Facial Expressions (Tottenham, 2009). The number of total affect faces to choose from were broken down into: 18 angry female, 17 fearful female, 17 angry male, 17 fearful male, 17 disgust female, 17 disgust male. Fifteen faces from each affect category were chosen for this task. Faces were chosen according to percent accuracy of identifying the affect displayed. All faces chosen were required to be above 80% accuracy. These 15 faces per category were then randomly assigned into one of the three different affect blocks, leaving five faces per category per block. As for the neutral faces, there were a total of 18 male neutral faces and 18 female neutral faces to choose from, all were used and five male faces were repeated to give us 23 male neutral faces total. Four female faces were repeated to give us 22 female neutral faces total. These 45 faces were then randomly assigned to one of three neutral blocks. An equal number of male and female faces were employed across the different blocks of the task.

Participants were instructed to respond to the gender of the face by pressing the key with their right index finger, if the face was male, and with their left index finger, if the face was female. The task lasted six minutes and 38 seconds and included three blocks per condition and 15 trials per block. The duration of each individual trial was 1 second (1,000 ms). Blocks followed the pattern: Neutral, Affect, Neutral, Affect, Neutral, Affect. Figure 1 is a schematic representation of the task as used in the study.

Procedure

All participants who contacted the Clinical Neuroscience Laboratory underwent a twenty-minute phone screening, where demographic and health history questionnaires were administered. Based on this information, participants who met the inclusion/exclusion criteria were invited to participate in the study. Once recruited, participants were asked to fill out various questionnaires related to overall health and mindfulness disposition. Participants then underwent a thirty minute neuroimaging session at the Wright Center for Innovation in Imaging at The Ohio State University. Both structural MRI and functional MRI were collected. During this session, participants were first told to lay in the scanner and rest, at which time structural and resting state scans were taken. Participants were then instructed to perform the Observe and Label task.

fMRI Acquisition

Functional and structural images were collected using a 3T Philips (Achieva) MRI system using an 8-channel receive only head coil. High resolution T1-weighted images were collected using a 3D magnetization-prepared rapid acquisition with gradient echo (MPRAGE) sequence with inversion time TI=1000, time between 180 degree pulses, TS=1000, short TR/TE=9.3/4.5ms, flip angle 9 degree, 0.9x1.1 mm in-plane resolution and 1.0 mm slice thickness and 5-minute scan time. fMRI data was acquired with Echo-Planar Imaging (EPI) using TR/TE of 250/30ms with 3x3x3mm resolution. This functional data was collected using a regularized least-squares approach to joint estimation of both the undistorted EPI image and field map at each acquisition using a spiral-in/spiral-out pulse sequence (see Sutton, Noll & Fessler, 2003).

Data Analysis

fMRI Analyses

Functional data during the Observe and Label Task were preprocessed and analyzed using fMRIB's software library (FSL 4.1.4 Smith et al., 2004, Woolrich, Behrens, Beckmann, Jenkinson, & Smith 2004). All acquired images were skull-stripped and corrected for interscanner movements and within-scan acquisition time differences between slices using FSL. All images were spatially smoothed using a 5-millimeter Gaussian smoothing kernel, full width half max (FWHM), and a temporal band pass filter of 0.008 Hz was applied to the data in order to filter out signals resulting from physiological responses in the scanner. Next, skull-stripped images for each participant were transformed into standardized brain space, Montreal

Neurological Institute (MNI) space, and then spatially registered to each participant's high-resolution scan.

Following pre-processing, first-level analysis was performed on the functional data using the FSL 4.1.4 tool FEAT (fMRI Expert Analysis Tool). For each subject, voxel-wise parameter estimate maps for the entire brain were estimated for each condition (affect, neutral) and the direct comparison between the conditions (affect>neutral). These parameter estimate maps were subsequently forwarded to two separate whole-head, group-level analyses.

To identify age-related differences in cortical activation during the emotion perception task, a group-level analysis was conducted examining average neural activation for each condition (affect, neutral) and the direct comparison between the conditions (affect > neutral). Individual-level parameter estimates for each condition contrast were entered into a mixed-effects repeated measures model, with groups (older adults, young adults) serving as a between-subject factor.

Secondly, in order to determine the association between mindfulness disposition and cortical activation in older adults, an additional whole-head, group-level analysis was performed using mindfulness disposition as a continuous variable. Participants' MAAS scores were standardized and entered as a regressor in a random-effects whole-brain group analysis, to examine regions of cortex that showed an association with mindfulness disposition and neural correlates of emotion perception. All data were thresholded at a voxelwise z-score of 1.96 and corrected for multiple comparisons at a *p*-value of 0.05.

Results

Age-related differences in cortical activation

Overall, our findings are consistent with previous literature demonstrating age-related differences in neural activation during an emotion perception task, as reflected by older adults' increased cognitive control over emotional reactivity. As depicted in *Figure 2*, age-related differences in cortical recruitment were evident during the different task conditions of the emotional perception task. In particular, during the Affect > Neutral condition, older adults, in comparison to young, demonstrated increased activation of the PFC, specifically the medial and lPFC regions involved in top-down controlled processes during emotion perception (see *Figure 2*) Additionally, older adults, relative to young , exhibited increased activation of the left temporal fusiform cortex during the Neutral > Affect condition. In contrast, young adults, relative to older adults, showed increased activation in the left parahippocampal gyrus, and the left amygdala and hippocampus region during the Affect>Neutral contrast (see *Figure 2; Table 2*), which may indicate increased emotional reactivity of young adults in response to negative emotional stimuli.

Association of mindfulness disposition with cortical activation patterns in older adults

In order to examine the association between mindfulness disposition and neural recruitment during affect processing, we conducted a whole-brain analysis, using trait levels of mindfulness disposition in our higher-level model as a variable of interest. Results showed that during the Affect > Neutral contrast, high levels of mindfulness disposition in older adults were associated with diminished reactivity in the orbitofrontal cortex and amygdala, areas heavily involved in emotion perception and automatic reactivity (*Figure* 3). This reduced functional activity while viewing the negative stimuli was also seen in the putamen, precentral gyrus, as well as, the parietal operculum cortex and planum temporale region (*Table 3.)* Thus, in line with our hypotheses, results indicated that higher levels of mindfulness disposition may enhance the neural circuitry involved in emotional perception via suppression of automatic amygdala activation.

Discussion

Although aging is often accompanied by cognitive decline (Dennis & Cabeza, 2008), older adults demonstrate an age-related increase in affective functioning capabilities, specifically showing superior emotion regulation abilities compared to young adults. Although this pattern of enhanced emotion regulation in aging has been widely accepted, the relation between mindfulness disposition, as an avenue for enhancing emotion regulation, and affective functioning of older adults has been relatively unexplored. The present study investigated both age-related differences in cortical recruitment during an emotion perception task, as well as the association of mindfulness disposition in older adults with neural circuitry involved in emotional processing. In particular, we were interested in examining whether older adults high in mindfulness disposition would show cortical activation patterns depicting enhanced cognitive control processes during emotion regulation. Our results confirmed differences in cortical activation between young and older adults, in line with previous findings of older adults' superior emotion regulation capabilities. In addition, our results confirmed an association between mindfulness disposition and the cortico-subcortico circuitry of emotional perception and further suggest that mindfulness disposition may have the capacity to optimize this neural pathway.

Overall, there appears to be a consistent pattern in aging involving decreases in amygdala activity, coupled with an increase in frontal activity, particularly in medial frontal regions, during emotional regulation processes. Based on this FADE pattern (St. Jacques et. al, 2009), we expected to see diminished amygdala activation coupled with greater PFC activation in older adults, relative to young adults, when viewing emotional stimuli, indicating older adults' enhanced ability to regulate emotions through greater cognitive control of emotions. Consistent with our hypothesis, older adults, relative to young, exhibited greater activation in the right medial and lateral prefrontal cortex in the Affect > Neutral condition, signifying an age-related enhancement of emotion regulation abilities. These findings indicated that older adults showed greater activation of cortical regions involved in top-down controlled processes during emotional perception, in line with previous literature suggesting that older adults may regulate their emotions through the strategy of cognitive reappraisal. This strategy of emotion regulation requires the individual to modify his or her emotional response by altering the interpretation of the stimulus (Gross, 1998). Engaging in reappraisal has been shown to increase activation in areas involved in executive control (Ochsner and Gross, 2005) such as the lateral and medial PFC, which are implicated in cognitive control (Beauregard et al., 2001; Ochsner et al., 2002; Levesque et al., 2003; Ochsner et al., 2004; Phan et al., 2005; Urry et al., 2006). Our results demonstrate this exact pattern of activation in older adults; furthermore, activation was lateralized to the right prefrontal regions, which research suggests is functionally specific to emotional input (Sackeim & Gur, 1978; Schwartz et al., 1975)

Also consistent with emotional aging literature, our findings indicated that young adults showed enhanced recruitment of areas associated with automatic reactivity. Explicitly, young adults, as compared to older adults, exhibited greater activation in the left parahippocampal gyrus spanning the amygdala and regions of the hippocampus during the Affect > Neutral condition, regions that have been associated with sensitivity to emotionally salient stimuli. More specifically, the amygdala is responsible for the automatic detection of emotions and the generation of physiological responses. In addition, research shows that young adults, as compared to older adults, tend to show greater amygdala activation when presented with negative emotional faces (Iidaka et al., 2002). Previous literature demonstrates that the parahippocampal gyrus and hippocampus are both involved in the encoding and storing of emotional memories as well as in the recognition of emotions. These results are in line with general emotional aging literature proposing that young adults are more reactive to emotional stimuli, as compared to older adults.

Recent research suggests that the practice of mindfulness may represent a pathway to the enhancement of emotion regulation abilities. Mindfulness disposition, defined as the ability to attend to and be aware of present moment experiences, has been shown to promote positive changes in overall mood and affective health (Carstensen et al, 2000). It is suggested that this shift toward positive mood occurs through the alteration and enhancement of emotion regulation abilities (Chambers, Gulone, & Allen, 2009). In order to examine the association between mindfulness disposition and cortical activation in older adults, a whole-brain analysis was performed using mindfulness disposition as a continuous variable. In here, we found changes in neural activation suggestive of enhancement in the neural correlates of emotional perception. Specifically, older adults high in mindfulness disposition demonstrated diminished reactivity in the left amygdala and the left OFC. The left lateralized amygdala specifically is responsive to negative emotional stimuli, such as the affect faces used in our Observe and Label Task (Morris et al., 1996; Lane et al., 1997, 1999; Blair et al., 1999; Dubois et al., 1999). Receiving strong inputs from the amygdala (Price et al., 1991), the OFC also plays a key role in decision-making as well as emotional judgment via appraisal the stimuli's emotional significance (Baron-Cohen et al., 1994; Damasio, 1994; Rolls, 1999). Taken together, results suggest that older adults higher in mindfulness disposition display less automatic reactivity to negative emotional stimuli, indicative of enhanced emotion regulation capabilities. These findings support the possibility of mindfulness as an avenue to improve emotion regulation and could help ensure high levels of affective well-being and emotional stability for older adults.

In general, there is a lack of research examining the association between mindfulness disposition and the affective functioning of older adults. To our knowledge, this is the first study that examines the effects of mindfulness disposition on emotional regulation in older adults. Our findings are the first to establish an association between mindfulness disposition and the neural correlates of emotion perception in older adults. These results, which are suggestive of underlying neural benefits of mindfulness, also support the idea that mindfulness is a possible avenue to strengthen emotion regulation capabilities. These findings may not be limited to an older adult population, but could potentially benefit various populations. Our results support the efficacy and importance of mindfulness and evince the value of formal clinical programs, such as MBSR, which promote the practice of mindfulness. However, there are potential limitations to this study, which should be taken into consideration when interpreting the results. Firstly, this study was a cross-sectional design which poses as a major limitation. The nature of a cross-sectional design is to collect data at one specific time point, providing only a snapshot of the outcome and characteristics associated with it; thus making it difficult to make any causal inference. Additionally, there has been an ongoing debate on the proper operationalization of the construct of mindfulness. Currently available measures vary in the facets of mindfulness that they capture. However, in the absence of a standardized technical definition of mindfulness, for this study we chose to quantify mindfulness disposition based on one of the most consistently used indices of mindfulness, the MAAS. One notable advantage of this questionnaire is its high internal consistency and test-retest reliability (Brown & Ryan, 2003).

Further research is needed to investigate the functional impact of trait mindfulness on overall emotion regulation and its relationship to the aging emotional brain. Additional analyses examining the functional connectivity of these cortical regions would help to establish the coupling of these areas as a function of mindfulness training. Examining the longitudinal effects of mindfulness practice would also be ideal to better understand the neural and behavioral benefits that result from the application of frequent mindfulness exercises. As such, further research endeavors include examining neurocognitive functioning before and after an eight-week MBSR intervention program that was completed by our older adult participants. This will give us insight to the direct cognitive and behavioral effects of mindfulness practice.

To summarize, consistent with the suggested concept of age-related enhancement of emotion regulation abilities, our findings indicated that young adults showed greater activation of areas associated with emotional reactivity, while older adults showed enhanced recruitment of cortical regions involved in top-down modulation and cognitive control processes during emotion perception. Importantly, our results also confirmed the existence of an association between mindfulness disposition and the neural correlates of emotion perception, such that higher mindfulness disposition in older adults was associated with diminished reactivity of the amygdala and OFC in response to negative facial stimuli. Taken together, the present study provides valuable insight into the capacity of mindfulness disposition to optimize the neural circuitry associated with emotional perception in older adults.

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Table 1

Demographics of Older and Young Adult Participants S.D. given in parentheses

	Older Adults	Young Adults
N	25	19
Age	65.88 (3.78)	24.68 (4.88)
Gender	Male=6 Female=19	Male=7 Female=12
Years of Education	15.72 (3.30)	16.11 (1.85)

Table 2

Statistical peaks in MNI space for the analysis of age-related differences in cortical activation

Cortical Area	**Label**	**Max z-stat**	**MNI Co-ordinates (mm)**		
			X	**Y**	**Z**
Old > Young					
Affect > Neutral					
Medial Prefrontal Cortex	mPFC	2.80	4	62	-6
Right Lateral Prefrontal Cortex	Rt. LPFC	3.18	42	46	16
Neutral > Affect					
Left Temporal Fusiform Cortex	Lt. TFC	3.01	-36	-32	-26
Young > Old					
Affect > Neutral					
Left Parahippocampal Gyrus	Lt. PGH	2.63	-28	-12	-32
Left Amygdala and Hippocampus	Lt. AMYG	2.42	-16	-12	-22

Table 3

Statistical peaks in MNI space for older adults higher in mindfulness disposition

Cortical Area	**Label**	**Max z-stat**	**MNI Co-ordinates (mm)**		
			X	**Y**	**Z**
Affect > Neutral					
Left Orbitofrontal Cortex	Lt. OFC	-3.34	-40	32	-2
Left Putamen	Lt. PUT	-3.01	-26	-10	4
Left Amygdala	Lt. AMYG	-2.94	-24	-10	-18
Left Precentral Gyrus	Lt. PrG	-2.72	-50	-2	30
Parietal Operculum Cortex Planum Temporale	Pfop/PT	-2.82	-50	-32	16

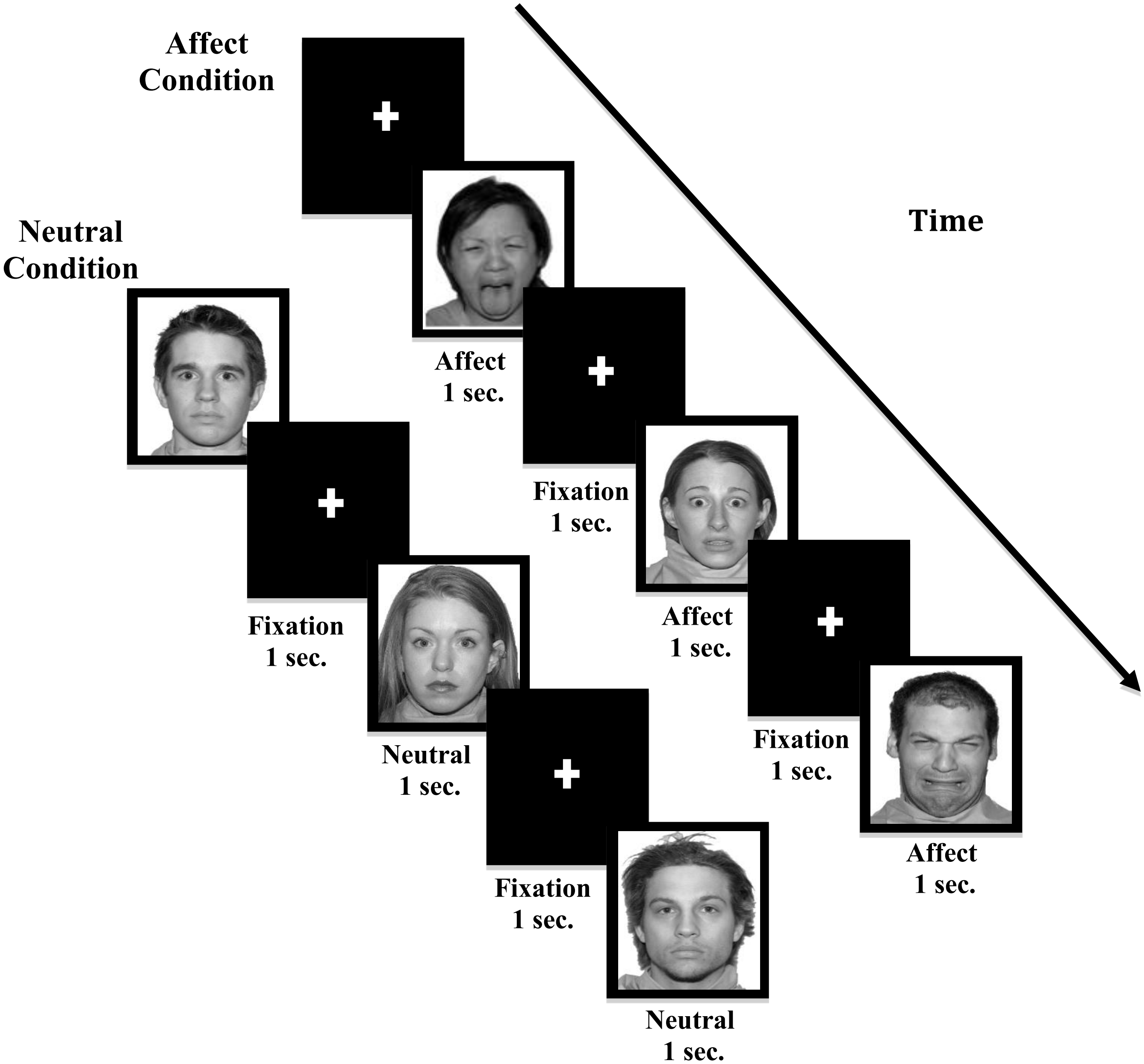

Figure 1. Graphical description of the Observe and Label task design with blocks of affect and neutral facial viewing interspersed with fixation periods. Participants are instructed to respond to the gender of the face.

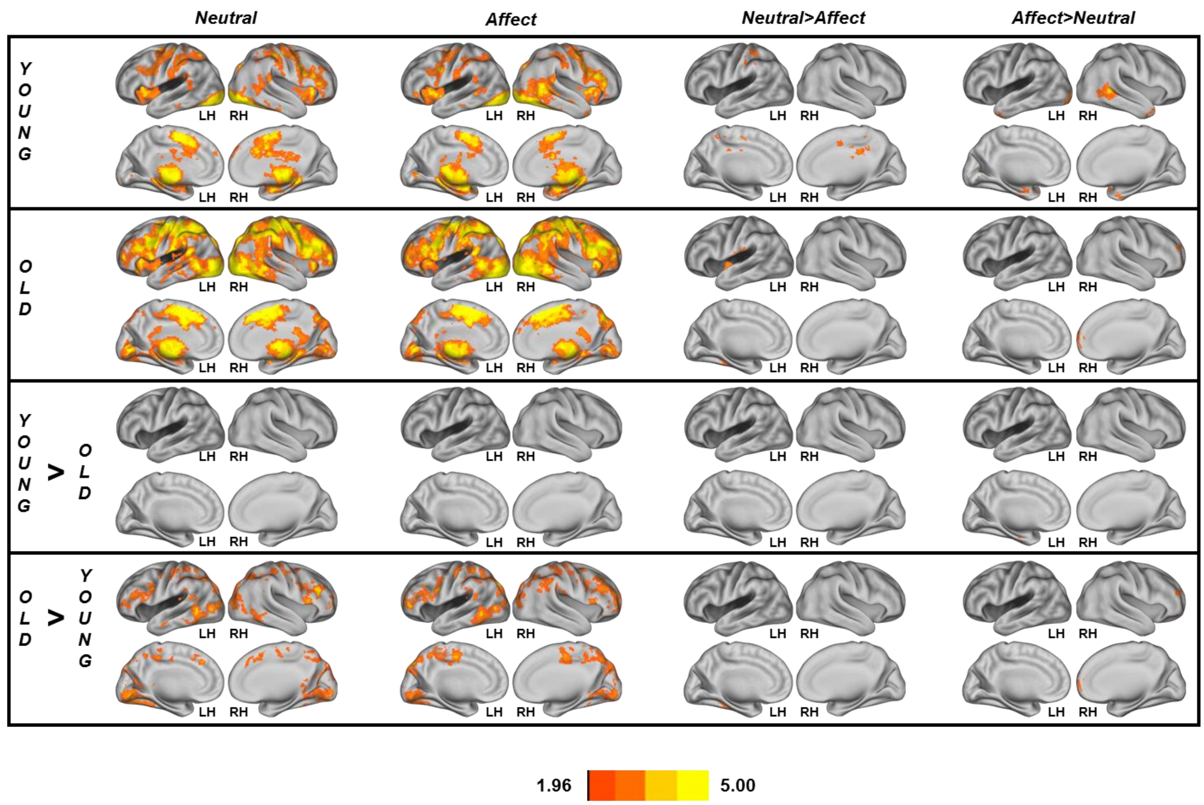

Figure 2. Averaged group activation in older and young adults during conditions of the Observe and Label task.

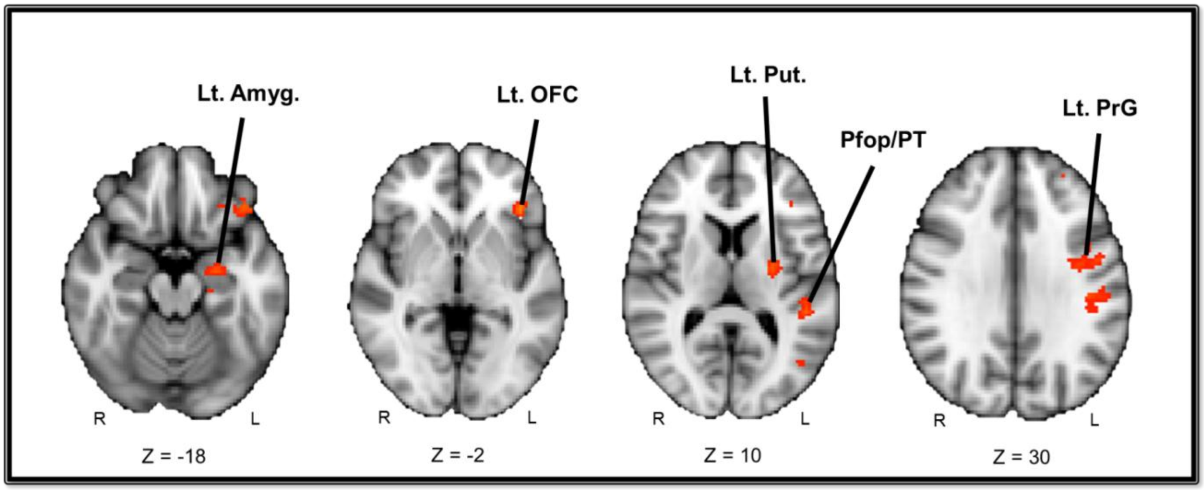

Figure 3. Cortical regions showing negative associations with mindfulness in Affect > Neutral in older adults.